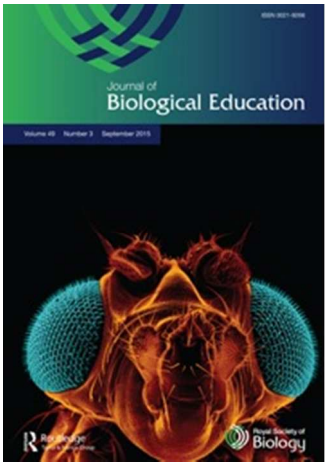

Budding biology teachers: what have botanical gardens got to offer inquiry learning

Journal:	*Journal of Biological Education*
Manuscript ID	RJBE-2016-0145.R2
Manuscript Type:	Research
Keywords:	inquiry learning, teacher views, botanical gardens, pre-service secondary teachers

Abstract

Teachers conceptualize inquiry learning in science learning differently. This is particularly evident when teachers are introduced to inquiry pedagogy within a new context. This exploratory study draws on semi-structured interviews conducted with eight pre-service secondary biology teachers following a day visit with university tutors to the Royal Botanical Gardens, Kew. Emerging findings were: first, pre-service biology teachers' views of inquiry learning range in sophistication from simple notions of 'learning from doing' to complex multi-notions such as student generated questions, developing curiosity and encouraging authentic scientific practices. Second, similarly their views of inquiry learning opportunities in botanical gardens ranged from simply places that offered 'memorable experiences' to enabling autonomous learning due to the organism diversity and multiple climates. Pre-service teachers categorised as having unsophisticated views of inquiry learning had limited expectations of botanical gardens as productive learning environments. Third, the majority of pre-service teachers were concerned about managing inquiry learning. A tension was identified between how open-ended an inquiry activity could be whilst ensuring student focus. Further, participants were concerned about the practical management of inquiry learning. We discuss implications for teacher educators and botanical garden educators and the requirement for curriculum development and promotion.

Keywords
Inquiry learning, teacher views, botanical gardens, pre-service secondary teachers

Title: Budding Biology Teachers: Pre-service Secondary Biology Teachers' views of Inquiry Learning when visiting a Botanical Garden

Introduction

Over the past decade, learning outside the classroom and inquiry learning have received increased research attention (Minner, Levy and Century 2009; Rocard et al. 2007). Studies indicate that both teaching in settings outside the classroom, such as botanical gardens, and inquiry learning increase student curiosity, engender collaborative learning and offer opportunities for authentic science learning (Braund and Reiss 2006). However, research consistently shows that teachers have diverse ways of expressing inquiry (Harrison 2014) and that implementation of both inquiry lessons (Crawford 2007) and teaching outside is challenging (Abd-El-Khalick and Akerson 2004; Kisiel 2013). Whilst there has been a handful of professional development programmes that have focused on inquiry learning in science outside the classroom, few studies have explored how the two approaches might interact and whether they support, hinder or influence how pre-service biology teachers view inquiry (Kisiel 2013).

Teacher's views on the purpose of science education, learning and teaching have been found to influence their response to professional development and, in turn, their pedagogical practice (Wallace 2014). It has been consistently found that the majority of pre-service secondary science teachers, on commencing the profession, view science as a body of knowledge imparted to students through classroom-bound didactic teaching approaches (Brown, Friedrichsen and Abell 2013). This view neglects consideration of scientific processes and does not recognize learning as complex and multi-dimensional requiring a range of teaching approaches. Further, pre-service teachers report being keen to teach outside the classroom but are concerned about things going wrong (Kisiel 2013). However, pre-service teachers' views and pedagogy are likely to be malleable in these early stages of their career, as they engage in professional development both through workshops at their university and in observing and teaching in their placement schools (Avraamidou 2012).

To ensure that professional development is effective, sequencing the introduction of new ideas and approaches needs careful consideration so that pre-service teachers are able to appreciate their synergies without feeling overwhelmed (Luft et al. 2011). Windschitl (2004) compelling demonstrates that pre-service teachers often have 'folk' notions of inquiry that are

largely shaped by their own experiences as science learners in traditional classrooms. However, there is currently a gap in the literature about how new teachers' views of inquiry might be influenced when introduced in a setting other than the classroom, in particular a botanical garden.

The aim of the research is to understand pre-service biology teachers' views of inquiry learning, when introduced for the first time during a teacher education programme, outside the classroom in a botanical garden. The research questions are:

1. How do pre-service biology teachers understand inquiry learning?
2. What inquiry learning opportunities do pre-service teachers consider botanical gardens offer?
3. What drawbacks do pre-service teachers anticipate to using botanical gardens for inquiry learning?
4. How are pre-service biology teachers' views of inquiry learning and botanical garden learning related?

Inquiry Learning in Science

In the past century, Dewey (1938) was one of the first educationalists to suggest inquiry as an effective and authentic way of learning. He stressed the importance of real life experiences and that inquiry skills help learners make sense of the world around them. This approach to learning encourages students to raise questions which are meaningful and often difficult, at first glance, to answer. The essence here is for teachers to avoid direct answers to these student-centred questions, and instead encourage students to take action by research, reasoning and exploration in an attempt to resolve the problem (Postman and Weingartner 1969). Through inquiry, students are able to develop a scientific way of thinking, which allows them to make sense of events, and acquire problem solving and other skills associated with lifelong learning.

Scientific inquiry is not easily defined as it varies greatly across the many domains of science and 'is often conflated with nature of Science' (Ledermann 2007, 835). Inquiry refers to the ways in which scientists go about their work, while nature of science refers to the intrinsic values and assumptions that constitute scientific knowledge. There are no fixed set of steps and methods that scientists always follow when doing an inquiry. While many schools might

teach about 'scientific method' and so infer that there is a recipe to follow, in fact, there are many approaches to inquiry working. An ecologist surveying a new site would work quite differently to a microbiologist testing the potency of a new antibiotic or a biochemist working out the molecular shape of a new substance. While Ledermann and colleagues purports the importance of explicitly teaching about nature of science, he also supports the idea of classroom inquiry: 'Students will best learn scientific concepts by doing science' (Lederman, Antink and Bartos 2014, 291).

There are, however, certain features of science that characterise an approach as a mode of inquiry. These centre around raising testable questions, forming hypotheses, seeking and evaluating evidence and analyzing and interpreting data to test or develop theory. They also include behaviours such as systematic ways of working, making observations and selecting instruments to enhance data collection, making decisions about how much data is needed to provide sufficient evidence to answer a question and controlling environments so that they can determine the relationship between variables. It provides students with both a way of explaining the phenomena they are introduced to in science and of predicting how similar events might play out when they meet them for the first time and so allows students to learn how to predict events. This is often referred to as developing an understanding of scientific method or the nature of science.

Taking an inquiry approach to science education is recognised as a multifaceted process (Linn, Davies and Bell 2004) and involves raising questions and seeking answers through the gathering of evidence. This question-driven approach generally involves the investigation of a problem or a phenomena (Kawalker and Vijapurker 2013) and so extends beyond simply using practical activity to illustrate relationships and concepts in science. Instead, the very essence of inquiry learning is about developing a scientific way of working, where learners find solutions to problems and consider how efficient and effective they have been in reaching an outcome. Sometimes, the problem is set by the teacher and students find various ways of reaching a solution, while alternatively students could raise a number of questions about a phenomena and seek a solution for each of these.

The Rocard Report (2007) advocated the need for a radical change in science pedagogy across Europe and encouraged science teachers to move to a more inquiry-led way of teaching. Over recent years, there have been several European Union projects, such as S-TEAM, ESTABLISH, Fibonacci, PRIMAS and SAILS, whose remit has been to support

groups of teachers across Europe in bringing about these changes in classroom practice. However, when exploring the approaches to inquiry that these individual projects have taken, it is clear that there is great variety in inquiry approach. Some have focused on **what scientists do** (for example, conducting investigations using scientific methods), while others on **how students learn** (for example, actively inquiring through thinking and doing). Yet other projects have emphasized the **pedagogical approach that teachers employ** (for example, designing extended investigations) (Minner, Levy and Century 2009).

There is therefore a range of inquiry approaches, some that remain teacher-led and others that offer more opportunity for student agency. In classrooms where students are allowed into the decision-making process, an inquiry approach offers opportunities for students to become more active in their learning with more involvement in the direction of activities. This moves students from taking a technical approach to science practical, where they simply follow a method and gather results, to a more scientific approach (Harrison 2014). Through inquiry science, students can make decisions about which questions to explore or which methodology to select or evaluate how confident they are in how results answer their initial question.

However, while there is not a unified definition of inquiry, there are agreed common features such as the active engagement of students and less teacher direction resulting in more pupil autonomy. Linn and colleague's description of inquiry includes the intentional process of diagnosing problems, critiquing experiments, considering alternatives, debating with peers and forming coherent arguments. Bybee (2009) identifies five similar features of inquiry as 'engagement' 'exploration' 'explanation' 'elaboration' and 'evaluation. Minner, Levy and Century (2009) also places the emphasis on the learners and their active involvement in raising and exploring scientifically oriented questions. The agreement is that learners are encouraged to take more responsibility to formulate explanations from evidence and evaluate these in light of alternative explanations, particularly those reflecting scientific understanding and how to communicate findings

While many science teachers purport the advantages of inquiry in science, it is widely accepted that most do not adopt an inquiry approach in their classrooms (Crawford 2000; Abrahams and Reiss 2012; Abrahams and Millar 2008). Crawford (2007) notes that teaching science through inquiry is complex, difficult and daunting for teachers. The concern is that when left to their own devices, students may fail to reach the kind of conceptual understanding teachers seek, but 'when students are too closely guided or directed, the

activity ceases to be 'doing science'' (Hodson 2014, 2535).

This is because teachers need to achieve a balance between taking an inquiry approach and encouraging conceptual development. Within an inquiry culture there is also a clear belief that student learning outcomes are especially valued (Crawford 2000). Students who are making observations, collecting data, analysing trends, synthesizing information, and drawing conclusions in authentic settings are developing skills that help them in problem-solving and also in understanding how they are learning. These inquiry skills are developed and experienced through working collaboratively with others and so communication, teamwork, and peer support are also vitally developed in inquiry classrooms (Harrison 2014). In the Primas Project (see www.primas-project.eu) all of the teachers were convinced that inquiry learning had a great potential to motivate students. However, both the approach and amount of inquiry learning that the teachers engaged in, depended on the subject that the teachers taught and also their perceptions of how that subject should be taught. Other factors, such as the systemic restrictions within their educational context, the likely impact on classroom management and resource restrictions tended to limit the amount and type of inquiry learning that teachers did in their classrooms. As Crawford suggested, there was a mismatch between teacher beliefs about the efficacy of approach and the practicalities of actually doing it in the classroom. Engstrom's activity model (1999) outlines the complexity of such systems, where the interaction between the actors, tools and objectives that are governed by practice within a community give rise to inner contradictions and conflicts. Advocated change in practice makes such systems even more sensitive to the change process and teachers often respond by converting the abstract contradiction and conflict into concrete reasons why change cannot be supported. With experienced teachers, the reasons are often located in resourcing, be it time or materials or simply an overladen curriculum to deliver. Our interest lay in the response from pre-service teachers to implementing inquiry learning.

Out of Classroom learning

Out-of-classroom settings present ideal environments for inquiry learning (Dutton et al., 2013). The botanic garden, for example, as an 'institution holding documented collections of living plants' (Wyse Jackson 1999) can support learning by introducing new, varied and authentic science experiences where students observe and investigate real-world science concepts and phenomena that are difficult, if not impossible, to replicate in school (Braund and Reiss 2006). That said, until recently traditional controlling didactic teaching and learning models have been frequently reported in botanic gardens settings (Sanders 2007).

Recognising the unleashed potential of outdoor settings, EU funded projects such as INQUIRE (Inquiry-based teacher training for a sustainable future) have aimed to demonstrate how inquiry learning in botanic gardens can inspire science teachers and their students and help address biodiversity and climate change (inquirebotany.org).

Outdoor settings, including botanic gardens, are infrequently incorporated into secondary science teachers' practice in England (O'Donnell, Morris, and Wilson 2006). Reasons science teachers report for the underuse include: lack of time (for example, time due to overloaded curriculum, deficiency of time in normal lesson and lack of time to organize), health and safety concerns, the visit usefulness/ educational worth, access to suitable sites and the financial cost (for example, staff cover, transport and entry) (Glackin and Jones 2012). Other reasons not directly reported include: science teachers' beliefs about what constitutes effective pedagogical practice and their self-efficacy to teach in different settings (Glackin 2016). There is limited research on pre-service secondary biology teachers' views of teaching outside the classroom or botanic gardens and teacher-education programmes often fail to address these challenges or stress the importance of outdoor educational experiences (Tal and Morag 2009).

Teacher's views on the purpose of science education, learning and teaching have been found to influence their response to professional development and in turn their pedagogical practice (Wallace 2014). It has been consistently found that the majority of pre-service secondary science teachers, on commencing the profession, view science as a body of knowledge imparted to students through classroom-bound didactic teaching approaches (Brown, Friedrichsen and Abell 2013). This view neglects consideration of scientific processes and does not recognize learning as complex and multi-dimensional requiring a range of teaching approaches. However, pre-service teachers' views and pedagogy are likely to be malleable in these early stages of their career, as they engage in professional development both through workshops at their university and in observing and teaching in their placement schools (Avraamidou 2012). To ensure that professional learning is effective, sequencing the introduction of new ideas and approaches needs careful consideration so that pre-service teachers are able to appreciate their synergies without feeling overwhelmed. Currently, there is a gap in the literature about how pre-service biology teachers' views of inquiry learning might be influenced when introduced in a setting other than the classroom, in particular a botanical garden.

The study

This paper draws on data from a small qualitative exploratory pilot study. Semi-structured interviews were conducted with eight pre-service secondary biology teachers at the latter stage of a one day visit to the Royal Botanical Gardens, Kew. The visit to Kew Gardens took place 2 months into the 9 month Post Graduate Certification in Education (PGCE) programme, when pre-service teachers had spent equal amounts of time in university and a placement school. The university education department focused on science/biology pedagogical subject knowledge and general learning theory. The pre-service teachers were graduates in biology-related subjects, with several holding Masters and doctorate degrees. All the participants were female which reflected the gender distribution in the biology PGCE cohort (16 females: 2 males). They ranged in ages between 23-37 years.

Prior to the visit the pre-service teachers had not received the formal two 3 hour sessions on inquiry-based learning which were planned for months 3 and 5. The focus of their training during the initial months had been more broad concerning understanding theories of learning, curriculum content and lesson planning. Similarly, they had received several sessions that had incorporated the use of local outdoor spaces into their science lessons but had yet to receive a formal session on using informal settings.

The visit programme was organised and taught by university PGCE biology tutors (both article authors). The day involved: an initial site orientation and introduction to the Garden's history (whereby maps were distributed); visiting a range of pre-selected sites (3) in the Garden to trial several inquiry-based science activities; and a final opportunity to collectively reflect on the Garden's potential for school biology learning. The inquiry-based activities were completed in small groups (2-3). They involved: questioning, observations and group discussion concerning plant adaptions. For example, one of the activities was in the Alpine House. On walking to the Alpine house, one of the tutors pointed out various plants and asked questions that encouraged the pre-service teachers to make observations and compare similarities and differences of plants preparing them with some of the language, terminology and approaches required for the activity. The pre-service teachers were asked to walk through the alpine house and pick out 3-4 plants that had adaptations for living at high altitude. The focus here was on making observations and inferences that they could then explain to others.

They were encouraged to seek further information online (using their mobile phones) and to ask details from their tutors where they were unsure of botanical terms or details. The students in their small groups practised explaining the adaptations for each of their selected plants before they joined with another group to 'teach' them about their selected plants. A list of general high altitude adaptations was collected and pre-service teachers were asked to recommend which plants demonstrated these the best. Finally, pre-service teachers were encouraged to read the information on the sign at the end of the Alpine house and decided how they might use this if they brought a class to the site.

The interviews were conducted by one of the authors; both authors are university PGCE biology tutors. Each participant completed a single, one-to-one, interview away from the main group towards the end of the session. Interviews were planned at this point as we wanted to capture data when pre-service biology teachers are potentially unfamiliar with inquiry-based learning in informal settings and are contemplating them for the first time. The interviews lasted a maximum of 10 minutes and were recorded. Interview questions included: What is inquiry learning?; What does inquiry learning offer science learning?; What might be the benefits of inquiry learning in a botanical garden? What might be the drawbacks of learning in a botanical garden? British Education Research Association's (2011) Ethical Guidelines were followed, included recommendations on *voluntary informed consent*, *right to withdraw* and *disclosure* (ensuring confidentiality and anonymity). The project received ethical approval from the university.

The interviews were transcribed and coded to reveal main themes generated from the data (see Charmaz 2011). The analysis focused on the responses from the pre-service teachers in order that we could ascertain both what the distinctive characteristics were in their conceptions of inquiry learning in an outdoor context and also how these related to the ways they were building models of teaching and learning. We searched for both similarities and differences between responses to enable us to postulate an interpretative framework that helped us make sense of their responses. Drawing on Lincoln and Guba's (1985) approach, following an initial coding of each participant's data for a particular research question – for example, understanding of inquiry –the codes were grouped into categories based on similarities. This process was iterative, that is as new codes emerged earlier data sets were returned to and reanalysed.

Findings

Research question 1: How do pre-service biology teachers understand inquiry learning?

In general terms, the majority of pre-service participants viewed inquiry as 'faithful to real science' and as 'authentic science'. The majority of pre-service teachers inferred that inquiry learning was not their experience of school science as either a student or a beginning teacher. Three participants, including Bethan below, suggested that inquiry learning would better prepare school students to study science at university level.

Pre-service biology teachers did not share one view of inquiry learning. Rather, at the latter stage of their visit, we identified three broad views of what constituted inquiry learning. We have termed these emergent views as: learning from doing, asking questions and developing curiosity. Only one participant viewed inquiry as *learning from doing,* explaining that inquiry involved 'learning through doing things and making mistakes' (Caroline).' This view is aligned with a trial and error approach similar to experiential learning (Kolb & Fry, 1975). For the majority of (7) participants, central to inquiry learning was *asking questions*. However, participants' views within this group varied in sophistication. Several participants (3) suggested inquiry was when teachers asked questions or were 'setting up problems' for students to explore. Sadaf, for example, said:

> 'Setting questions that are quite broad and then encourage learners to develop questions to lead to own answers. It is quite organic process and there will not necessarily be a right answer.'

The third broad inquiry view, *developing curiosity*, we considered as holistic and complex, whereby participants (2) talked not only about asking, prompting questions and answering questions through doing but also discussed inquiry as the need for observations to prompt thinking, develop technical skills and engender both scientific and place-based curiosity. For example, Bethan's view of inquiry was considered complex, underpinned by the view that inquiry concerned students' curiosity:

> 'I think it([inquiry)is quite loose and I think it is about exploring and …. about giving a lot of scope to children to learn to investigate things and think about things that they

> have not thought about and they come up with questions that you as a teacher wouldn't have thought of asking and it is about being inquisitive …….and it is a really good way to engage children in science as it is absolutely what it is about in university and beyond. It is about taking the problem and coming up with the solution but more than that it is about working out how to use the apparatus, that we already have, to investigate - which I think is a neglected skill at the moment…. As a lot of skills and definitions you can learn but being inquisitive you have to find and develop rather than just be taught it.'

Research question 2: What inquiry learning science opportunities do pre-service teachers consider botanical gardens offer?

Pre-service biology teachers identified various inquiry learning-related opportunities available in botanical gardens. The majority of the inquiry opportunities listed were not specific to the context of a botanical gardens but rather could be transferred to multiple informal settings. That is, participants listed inquiry opportunities as: prompting questions, stimulating thought, triggering curiosity ('seeing strange things') and creating the possibility for self-directed and autonomous learning. Frequently, participants conflated inquiry learning with learning outside the classroom, such as a botanical garden. For example, in response to a question concerning inquiry learning four participants highlighted that the Garden offered 'memorable experiences' and 'authentic science'.

For the two participants who did identify opportunities specific to a botanical garden, developing scientific observation was key. This affordance was aligned with the opportunity for conceptual understanding in biology-related topics including variation, adaptation and evolution. Emily, for example, suggested that botanical gardens offered an opportunity to study organisms in their 'natural' environment: 'I think for science, seeing plants and animals in their climates it is really useful in relation to adaptions and evolution' and Bethan suggested the Gardens offered an opportunity 'to see that there is a whole Alpine house of multiple examples' to compare and consider.

Research question 3: What drawbacks do pre-service biology teachers anticipate to using botanical gardens for inquiry learning?

The pre-service biology teachers had few concerns about using botanical gardens for inquiry learning with several (3) participants stating that they could think of no drawbacks or concerns. This is counter to the prevailing belief that the majority of pre-service teachers are very concerned about teaching outside the classroom (Kisiel 2013). However, when participants did voice concerns they generally were related to managing inquiry learning. That is, first, a tension was identified between how open-ended an inquiry-based activity could be whilst maintaining student focus. For example, Emily, acknowledging the tension, highlighted the importance of an effective teacher-student relationship:

> 'It is such a large area. It could be difficult to control students. You need a good relationship with them and want to give them tasks that they can really focus on. So not just wandering around looking at things so that they might get a bit bored. There is a fine balance between searching out something, and really thinking about it, and just wandering about and getting bored.'

Similarly, Gina discussed the tension in terms of trust between teacher and students:

> 'So the drawback will be that it will be difficult to hand it over to them and hope they come up with questions and curiosities. I think it is a lot of trust…..If you've had the class for a while and you have trained them to think they probably will do quite well so it will depend on the class.'

The second concern related to managing inquiry learning was in terms of the practicalities. Hence, participants, referring to the Garden, were concerned about: the lack of physical boundaries (for example, classroom walls), the students' interaction with the general public and the potential health risks (for example, poisoning from plants and falling over).

Research question 4: How are pre-service biology teachers' views of inquiry learning and botanical garden learning related?

In answering this question, we explored the relationships between the pre-service teachers views of inquiry learning as they tried to articulate how this might be developed in a botanical garden. It was clear that many of the views that steered the pre-service teachers'

ideas about the nature of science, inquiry and pedagogy were also prevalent when they considered teaching outdoors. This enabled us to develop an interpretative framework (Table 1) to understand better the range of views expressed. Hence, when we explored the participant's views of inquiry learning alongside their views of inquiry opportunities in botanical gardens, three broad categories of views emerged which ranged from naïve (View 1) through to developing sophistication (View 3). So pre-service biology teachers' with a view of inquiry as 'learning from doing' were found to view inquiry opportunities in botanical gardens as offering 'memorable experiences'. We categorized these views as simple and uncomplicated with limited affordances expressed for inquiry learning outside the classroom (View 1). Whereas, pre-service biology teachers with a view of inquiry as complex, driven by curiosity, expressed through questioning and scientific observation were found to view inquiry outside the classroom as an opportunity to encourage students' autonomy by cultivating students' scientific interest in 'authentic settings'. These pre-service teachers realized that there were increased opportunities for inquiry learning offered by the botanical garden. We categorized these views as complex, as whilst these pre-service teachers understood the affordances for inquiry in outdoor settings they also acknowledged the settings' challenges.

Table 1: here

Participants categorized with naive views (View 1) of inquiry learning and learning in informal settings were generally identified as focused on the requirements of the curriculum and formal assessments. Caroline, was categorised as having View 1:

> 'If they are doing inquiry based learning it might not be always brought back to the syllabus that they are learning ….It might not be relevant to the exam question they are eventually going to answer…The examples are not as structured or specific to the syllabus they are learning but it might help them later on and in later years. There is a lot of avenues to go down in Kew, but if you are teaching in the classroom you are teaching to the curriculum, that's what you are sticking to for example, so they don't get confused. For the more able students they know what is relevant, to what they need to answer in the question, to what isn't. For lower ability learners, although it is good for them to do things that are practical, they might not be able to differentiate

between what applies to the question, that is what they need to know, and what is extra information.'

Participants categorized with complex views concerning inquiry learning and learning in informal settings stressed the need 'to ensure maximum benefits' of the visit by tying the inquiry learning from the Garden back into the classroom and vice versa. That is, the visit needed to be integrated into the learning sequence so that pre-and post-activities were thoroughly planned. Although similar, this view was articulated differently from the explicit need to link learning to the curriculum or to formal assessments. Rather, pre-service teachers categorized with a complex view (View 3), foresaw the potential challenges to ensure that whilst inquiry learning built on students' prior knowledge, this learning needed to be transferred into the real world setting and eventually brought back to, and made sense off, in the classroom. These insights presented challenges for two participants as they initially spoke about inquiry learning enabling student autonomy, but struggled to articulate a pedagogy that enabled this, without giving up the control they felt they required:

'What will be difficult will be doing a follow-up class that really gets the benefit of what they have found. I think it is really important to ask students what they have learnt and, in fact, do it before - tell them what they are looking for - as I think it would be quite easy to wander around and say that is a pretty plant and not think about it. So it is important to give students good questions to think for themselves to give them how to look and what to look for and follow it up afterwards……. I think in a pre-class, you could give them basic questions or, in school, we gave them question words and we gave them keywords and we asked them to put them together to make questions. As I do not think you can say to a child - come up with a question or a good question, especially if you want next level (higher order) questioning.' (Gina)

Implications

Our findings indicate that innovation is difficult to implement, even when introduced early in emergent pedagogy, as with these pre-service Biology teachers. For some pre-service teachers, the complexity of what the inquiry practice might construe proved too great a step for them to envisage. For others, while there was an appetite for introducing inquiry learning

to help students explore and make meaning in an outdoor setting, several contradictions and conflicts arose (Engstrom 1999), which led to constraints in the implementation. This has led us to believe that a longer time frame and more staged introduction to inquiry learning is required, before we add the challenge of performing inquiry in an outdoor setting.

At a local level, the three level variation in response from the pre-service biology teachers has led us to consider the course sessions that we provide on the nature of science, inquiry and learning in informal settings and how we might more readily support beginning teachers in developing appropriate pedagogies. This may mean that we need to take a more differentiated approach to the earlier part of the pre-service course so that pre-service teachers can, in their own time, come to terms with how they introduce and blend these types of pedagogy into practice. Expanding the vision of where science inquiry learning can happen early for beginning teachers may increase their interest and confidence in the use of the outdoor learning environments for science teaching (Fiennes et al. 2015) and pre-service courses may need to be more flexible in accommodating diverse needs as beginning teachers' pedagogy emerges.

For schools, we feel that a similar problem exists. Outdoor learning is a novel approach for many teachers and attempting to transform the 'normal classroom teaching' in approach, as well as context, may be too great a challenge to achieve in a single visit. We would therefore advocate a series of linked visits to an outdoor setting, so that teachers can gradually make sense of their context and gain the confidence to allow more student agency for learning in an outdoor setting. An alternative or addition to this might be a linked introduction and followup session for the outdoor visit within the normal classroom to allow a more mediated and gentler introduction to inquiry learning.

Conclusion

This paper has considered the views of pre-service secondary science teachers of inquiry learning during a visit to a botanical garden. Pre-service biology teachers differed in the ways they responded to an opportunity to develop inquiry learning in a botanic garden setting. Evidence suggests that pre-service science teachers are aware of the affordances of inquiry learning. However, they are concerned about ensuring a diversity of learning outcomes, the control of learning and the potential direction and openness of inquiry. This concern is

compounded by the richness and diversity on offer in botanical gardens to inquiry. Taken together, these factors bring a unique set of challenges that have the potential to overwhelm pre-service teachers in the early stages of their professional development. Trying to make sense of a pedagogy that suggested greater student agency caused them varying degrees of concern as to the feasibility of such an approach, while their varying conceptualisations of the nature of science encouraged many of them to consider how it might develop students' curiosity and motivation.

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Table 1.
Pre-service biology teachers' view of inquiry learning and botanical garden learning

Description of inquiry learning and botanical garden learning views	**Teachers' view of inquiry learning**	**Teachers' view of inquiry opportunities in botanical gardens**
View 1: Simple/technical uncomplicated view of inquiry and informal settings	Learning from doing, making mistakes	Memorable experience
View 2: Inquiry learning and informal setting learning viewed as opportunity to initiate student agency over science learning	Teacher set up questions but also encourage students to set own questions Making observations to think.	Space used to answer questions, collect evidence, find the right answer and stimulate thought, provides material for thinking. It is where 'real science' occurs, similar to in universities
View 3: Views inquiry learning as complex. Considers inquiry in botanical gardens as useful context for skill & conceptual development.	As above, plus develop technical skills, engender both scientific and place-based curiosity	Space to open up curiosity, offering 'authentic' science similar to university science. It is self-directed which cultivates students' interest in the real world. Offers multiple examples of organisms living in situ for studies including adaptation, evolution, and variation.

Abstract

Teachers conceptualize inquiry learning in science learning differently. This is particularly evident when teachers are introduced to inquiry pedagogy within a new context. This exploratory study draws on semi-structured interviews conducted with eight pre-service secondary biology teachers following a day visit with university tutors to the Royal Botanical Gardens, Kew. Emerging findings were: first, pre-service biology teachers' views of inquiry learning range in sophistication from simple notions of 'learning from doing' to complex multi-notions such as student generated questions, developing curiosity and encouraging authentic scientific practices. Second, similarly their views of inquiry learning opportunities in botanical gardens ranged from simply places that offered 'memorable experiences' to enabling autonomous learning due to the organism diversity and multiple climates. Pre-service teachers categorised as having unsophisticated views of inquiry learning had limited expectations of botanical gardens as productive learning environments. Third, the majority of pre-service teachers were concerned about managing inquiry learning. A tension was identified between how open-ended an inquiry activity could be whilst ensuring student focus. Further, participants were concerned about the practical management of inquiry learning. We discuss implications for teacher educators and botanical garden educators and the requirement for curriculum development and promotion.

Keywords
Inquiry learning, teacher views, botanical gardens, pre-service secondary teachers

Title: Budding Biology Teachers: Pre-service Secondary Biology Teachers' views of Inquiry Learning when visiting a Botanical Garden

Introduction

Over the past decade, learning outside the classroom and inquiry learning have received increased research attention (Minner, Levy and Century 2009; Rocard et al. 2007). Studies indicate that both teaching in settings outside the classroom, such as botanical gardens, and inquiry learning increase student curiosity, engender collaborative learning and offer opportunities for authentic science learning (Braund and Reiss 2006). However, research consistently shows that teachers have diverse ways of expressing inquiry (Harrison 2014) and that implementation of both inquiry lessons (Crawford 2007) and teaching outside is challenging (Abd-El-Khalick and Akerson 2004; Kisiel 2013). Whilst there has been a handful of professional development programmes that have focused on inquiry learning in science outside the classroom, few studies have explored how the two approaches might interact and whether they support, hinder or influence how pre-service biology teachers view inquiry (Kisiel 2013).

Teacher's views on the purpose of science education, learning and teaching have been found to influence their response to professional development and, in turn, their pedagogical practice (Wallace 2014). It has been consistently found that the majority of pre-service secondary science teachers, on commencing the profession, view science as a body of knowledge imparted to students through classroom-bound didactic teaching approaches (Brown, Friedrichsen and Abell 2013). This view neglects consideration of scientific processes and does not recognize learning as complex and multi-dimensional requiring a range of teaching approaches. Further, pre-service teachers report being keen to teach outside the classroom but are concerned about things going wrong (Kisiel 2013). However, pre-service teachers' views and pedagogy are likely to be malleable in these early stages of their career, as they engage in professional development both through workshops at their university and in observing and teaching in their placement schools (Avraamidou 2012).

To ensure that professional development is effective, sequencing the introduction of new ideas and approaches needs careful consideration so that pre-service teachers are able to appreciate their synergies without feeling overwhelmed (Luft et al. 2011). Windschitl (2004) compelling demonstrates that pre-service teachers often have 'folk' notions of inquiry that are

largely shaped by their own experiences as science learners in traditional classrooms. However, there is currently a gap in the literature about how new teachers' views of inquiry might be influenced when introduced in a setting other than the classroom, in particular a botanical garden.

The aim of the research is to understand pre-service biology teachers' views of inquiry learning, when introduced for the first time during a teacher education programme, outside the classroom in a botanical garden. The research questions are:

1. How do pre-service biology teachers understand inquiry learning?
2. What inquiry learning opportunities do pre-service teachers consider botanical gardens offer?
3. What drawbacks do pre-service teachers anticipate to using botanical gardens for inquiry learning?
4. How are pre-service biology teachers' views of inquiry learning and botanical garden learning related?

Inquiry Learning in Science

In the past century, Dewey (1938) was one of the first educationalists to suggest inquiry as an effective and authentic way of learning. He stressed the importance of real life experiences and that inquiry skills help learners make sense of the world around them. This approach to learning encourages students to raise questions which are meaningful and often difficult, at first glance, to answer. The essence here is for teachers to avoid direct answers to these student-centred questions, and instead encourage students to take action by research, reasoning and exploration in an attempt to resolve the problem (Postman and Weingartner 1969). Through inquiry, students are able to develop a scientific way of thinking, which allows them to make sense of events, and acquire problem solving and other skills associated with lifelong learning.

Scientific inquiry is not easily defined as it varies greatly across the many domains of science and 'is often conflated with nature of Science' (Ledermann 2007, 835). Inquiry refers to the ways in which scientists go about their work, while nature of science refers to the intrinsic values and assumptions that constitute scientific knowledge. There are no fixed set of steps and methods that scientists always follow when doing an inquiry. While many schools might

teach about 'scientific method' and so infer that there is a recipe to follow, in fact, there are many approaches to inquiry working. An ecologist surveying a new site would work quite differently to a microbiologist testing the potency of a new antibiotic or a biochemist working out the molecular shape of a new substance. While Ledermann and colleagues purports the importance of explicitly teaching about nature of science, he also supports the idea of classroom inquiry: 'Students will best learn scientific concepts by doing science' (Lederman, Antink and Bartos 2014, 291).

There are, however, certain features of science that characterise an approach as a mode of inquiry. These centre around raising testable questions, forming hypotheses, seeking and evaluating evidence and analyzing and interpreting data to test or develop theory. They also include behaviours such as systematic ways of working, making observations and selecting instruments to enhance data collection, making decisions about how much data is needed to provide sufficient evidence to answer a question and controlling environments so that they can determine the relationship between variables. It provides students with both a way of explaining the phenomena they are introduced to in science and of predicting how similar events might play out when they meet them for the first time and so allows students to learn how to predict events. This is often referred to as developing an understanding of scientific method or the nature of science.

Taking an inquiry approach to science education is recognised as a multifaceted process (Linn, Davies and Bell 2004) and involves raising questions and seeking answers through the gathering of evidence. This question-driven approach generally involves the investigation of a problem or a phenomena (Kawalker and Vijapurker 2013) and so extends beyond simply using practical activity to illustrate relationships and concepts in science. Instead, the very essence of inquiry learning is about developing a scientific way of working, where learners find solutions to problems and consider how efficient and effective they have been in reaching an outcome. Sometimes, the problem is set by the teacher and students find various ways of reaching a solution, while alternatively students could raise a number of questions about a phenomena and seek a solution for each of these.

The Rocard Report (2007) advocated the need for a radical change in science pedagogy across Europe and encouraged science teachers to move to a more inquiry-led way of teaching. Over recent years, there have been several European Union projects, such as S-TEAM, ESTABLISH, Fibonacci, PRIMAS and SAILS, whose remit has been to support

groups of teachers across Europe in bringing about these changes in classroom practice. However, when exploring the approaches to inquiry that these individual projects have taken, it is clear that there is great variety in inquiry approach. Some have focused on **what scientists do** (for example, conducting investigations using scientific methods), while others on **how students learn** (for example, actively inquiring through thinking and doing). Yet other projects have emphasized the **pedagogical approach that teachers employ** (for example, designing extended investigations) (Minner, Levy and Century 2009).

There is therefore a range of inquiry approaches, some that remain teacher-led and others that offer more opportunity for student agency. In classrooms where students are allowed into the decision-making process, an inquiry approach offers opportunities for students to become more active in their learning with more involvement in the direction of activities. This moves students from taking a technical approach to science practical, where they simply follow a method and gather results, to a more scientific approach (Harrison 2014). Through inquiry science, students can make decisions about which questions to explore or which methodology to select or evaluate how confident they are in how results answer their initial question.

However, while there is not a unified definition of inquiry, there are agreed common features such as the active engagement of students and less teacher direction resulting in more pupil autonomy. Linn and colleague's description of inquiry includes the intentional process of diagnosing problems, critiquing experiments, considering alternatives, debating with peers and forming coherent arguments. Bybee (2009) identifies five similar features of inquiry as 'engagement' 'exploration' 'explanation' 'elaboration' and 'evaluation. Minner, Levy and Century (2009) also places the emphasis on the learners and their active involvement in raising and exploring scientifically oriented questions. The agreement is that learners are encouraged to take more responsibility to formulate explanations from evidence and evaluate these in light of alternative explanations, particularly those reflecting scientific understanding and how to communicate findings

While many science teachers purport the advantages of inquiry in science, it is widely accepted that most do not adopt an inquiry approach in their classrooms (Crawford 2000; Abrahams and Reiss 2012; Abrahams and Millar 2008). Crawford (2007) notes that teaching science through inquiry is complex, difficult and daunting for teachers. The concern is that when left to their own devices, students may fail to reach the kind of conceptual understanding teachers seek, but 'when students are too closely guided or directed, the

activity ceases to be 'doing science'' (Hodson 2014, 2535).

This is because teachers need to achieve a balance between taking an inquiry approach and encouraging conceptual development. Within an inquiry culture there is also a clear belief that student learning outcomes are especially valued (Crawford 2000). Students who are making observations, collecting data, analysing trends, synthesizing information, and drawing conclusions in authentic settings are developing skills that help them in problem-solving and also in understanding how they are learning. These inquiry skills are developed and experienced through working collaboratively with others and so communication, teamwork, and peer support are also vitally developed in inquiry classrooms (Harrison 2014). In the Primas Project (see www.primas-project.eu) all of the teachers were convinced that inquiry learning had a great potential to motivate students. However, both the approach and amount of inquiry learning that the teachers engaged in, depended on the subject that the teachers taught and also their perceptions of how that subject should be taught. Other factors, such as the systemic restrictions within their educational context, the likely impact on classroom management and resource restrictions tended to limit the amount and type of inquiry learning that teachers did in their classrooms. As Crawford suggested, there was a mismatch between teacher beliefs about the efficacy of approach and the practicalities of actually doing it in the classroom. Engeström's activity model (1999) outlines the complexity of such systems, where the interaction between the actors, tools and objectives that are governed by practice within a community give rise to inner contradictions and conflicts. Advocated change in practice makes such systems even more sensitive to the change process and teachers often respond by converting the abstract contradiction and conflict into concrete reasons why change cannot be supported. With experienced teachers, the reasons are often located in resourcing, be it time or materials or simply an overladen curriculum to deliver. Our interest lay in the response from pre-service teachers to implementing inquiry learning.

Out of Classroom learning

Out-of-classroom settings present ideal environments for inquiry learning (Dutton et al., 2013). The botanic garden, for example, as an 'institution holding documented collections of living plants' (Wyse Jackson 1999) can support learning by introducing new, varied and authentic science experiences where students observe and investigate real-world science concepts and phenomena that are difficult, if not impossible, to replicate in school (Braund and Reiss 2006). That said, until recently traditional controlling didactic teaching and learning models have been frequently reported in botanic gardens settings (Sanders 2007). Recognising the unleashed potential of outdoor settings, EU funded projects such as INQUIRE (Inquiry-based teacher training for a sustainable future) have aimed to demonstrate how inquiry learning in botanic gardens can inspire science teachers and their students and help address biodiversity and climate change (inquirebotany.org).

Outdoor settings, including botanic gardens, are infrequently incorporated into secondary science teachers' practice in England (O'Donnell, Morris, and Wilson 2006). Reasons science teachers report for the underuse include: lack of time (for example, time due to

overloaded curriculum, deficiency of time in normal lesson and lack of time to organize), health and safety concerns, the visit usefulness/ educational worth, access to suitable sites and the financial cost (for example, staff cover, transport and entry) (Glackin and Jones 2012). Other reasons not directly reported include: science teachers' beliefs about what constitutes effective pedagogical practice and their self-efficacy to teach in different settings (Glackin 2016). There is limited research on pre-service secondary biology teachers' views of teaching outside the classroom or botanic gardens and teacher-education programmes often fail to address these challenges or stress the importance of outdoor educational experiences (Tal and Morag 2009).

Teacher's views on the purpose of science education, learning and teaching have been found to influence their response to professional development and in turn their pedagogical practice (Wallace 2014). It has been consistently found that the majority of pre-service secondary science teachers, on commencing the profession, view science as a body of knowledge imparted to students through classroom-bound didactic teaching approaches (Brown, Friedrichsen and Abell 2013). This view neglects consideration of scientific processes and does not recognize learning as complex and multi-dimensional requiring a range of teaching approaches. However, pre-service teachers' views and pedagogy are likely to be malleable in these early stages of their career, as they engage in professional development both through workshops at their university and in observing and teaching in their placement schools (Avraamidou 2012). To ensure that professional learning is effective, sequencing the introduction of new ideas and approaches needs careful consideration so that pre-service teachers are able to appreciate their synergies without feeling overwhelmed. Currently, there is a gap in the literature about how pre-service biology teachers' views of inquiry learning might be influenced when introduced in a setting other than the classroom, in particular a botanical garden.

The study

This paper draws on data from a small qualitative exploratory pilot study. Semi-structured interviews were conducted with eight pre-service secondary biology teachers at the latter stage of a one day visit to the Royal Botanical Gardens, Kew. The visit to Kew Gardens took place 2 months into the 9 month Post Graduate Certification in Education (PGCE) programme, when pre-service teachers had spent equal amounts of time in university and a placement school. The university education department focused on science/biology

pedagogical subject knowledge and general learning theory. The pre-service teachers were graduates in biology-related subjects, with several holding Masters and doctorate degrees. All the participants were female which reflected the gender distribution in the biology PGCE cohort (16 females: 2 males). They ranged in ages between 23-37 years.

Prior to the visit the pre-service teachers had not received the formal two 3-hour sessions on inquiry-based learning which were planned for months 3 and 5. The focus of their training during the initial months had been more broad concerning understanding theories of learning, curriculum content and lesson planning. Similarly, they had received several sessions that had incorporated the use of local outdoor spaces into their science lessons but had yet to receive a formal session on using informal settings.

The visit programme was organised and taught by university PGCE biology tutors (both article authors). The day involved: an initial site orientation and introduction to the Garden's history (whereby maps were distributed); visiting a range of pre-selected sites (3) in the Garden to trial several inquiry-based science activities; and a final opportunity to collectively reflect on the Garden's potential for school biology learning. The inquiry-based activities were completed in small groups (2-3). They involved: questioning, observations and group discussion concerning plant adaptions. For example, one of the activities was in the Alpine House. On walking to the Alpine house, one of the tutors pointed out various plants and asked questions that encouraged the pre-service teachers to make observations and compare similarities and differences of plants preparing them with some of the language, terminology and approaches required for the activity. The pre-service teachers were asked to walk through the alpine house and pick out 3-4 plants that had adaptations for living at high altitude. The focus here was on making observations and inferences that they could then explain to others. They were encouraged to seek further information online (using their mobile phones) and to ask details from their tutors where they were unsure of botanical terms or details. The students in their small groups practised explaining the adaptations for each of their selected plants before they joined with another group to 'teach' them about their selected plants. A list of general high altitude adaptations was collected and pre-service teachers were asked to recommend which plants demonstrated these the best. Finally, pre-service teachers were encouraged to read the information on the sign at the end of the Alpine house and decided how they might use this if they brought a class to the site.

The interviews were conducted by one of the authors; both authors are university PGCE biology tutors. Each participant completed a single, one-to-one, interview away from the main group towards the end of the session. Interviews were planned at this point as we wanted to capture data when pre-service biology teachers are potentially unfamiliar with inquiry-based learning in informal settings and are contemplating them for the first time. The interviews lasted a maximum of 10 minutes and were recorded. Interview questions included: What is inquiry learning?; What does inquiry learning offer science learning?; What might be the benefits of inquiry learning in a botanical garden? What might be the drawbacks of learning in a botanical garden? British Education Research Association's (2011) Ethical Guidelines were followed, included recommendations on *voluntary informed consent*, *right to withdraw* and *disclosure* (ensuring confidentiality and anonymity). The project received ethical approval from the university.

The interviews were transcribed and coded to reveal main themes generated from the data (see Charmaz 2011). The analysis focused on the responses from the pre-service teachers in order that we could ascertain both what the distinctive characteristics were in their conceptions of inquiry learning in an outdoor context and also how these related to the ways they were building models of teaching and learning. We searched for both similarities and differences between responses to enable us to postulate an interpretative framework that helped us make sense of their responses. Drawing on Lincoln and Guba's (1985) approach, following an initial coding of each participant's data for a particular research question – for example, understanding of inquiry –the codes were grouped into categories based on similarities. This process was iterative, that is as new codes emerged earlier data sets were returned to and reanalysed.

Findings

Research question 1: How do pre-service biology teachers understand inquiry learning?

In general terms, the majority of pre-service participants viewed inquiry as 'faithful to real science' and as 'authentic science'. The majority of pre-service teachers inferred that inquiry learning was not their experience of school science as either a student or a beginning teacher. Three participants, including Bethan below, suggested that inquiry learning would better prepare school students to study science at university level.

Pre-service biology teachers did not share one view of inquiry learning. Rather, at the latter stage of their visit, we identified three broad views of what constituted inquiry learning. We have termed these emergent views as: learning from doing, asking questions and developing curiosity. Only one participant viewed inquiry as *learning from doing,* explaining that inquiry involved 'learning through doing things and making mistakes' (Caroline).' This view is aligned with a trial and error approach similar to experiential learning (Kolb & Fry, 1975). For the majority of (7) participants, central to inquiry learning was *asking questions*. However, participants' views within this group varied in sophistication. Several participants (3) suggested inquiry was when teachers asked questions or were 'setting up problems' for students to explore. Sadaf, for example, said:

> 'Setting questions that are quite broad and then encourage learners to develop questions to lead to own answers. It is quite organic process and there will not necessarily be a right answer.'

The third broad inquiry view, *developing curiosity*, we considered as holistic and complex, whereby participants (2) talked not only about asking, prompting questions and answering questions through doing but also discussed inquiry as the need for observations to prompt thinking, develop technical skills and engender both scientific and place-based curiosity. For example, Bethan's view of inquiry was considered complex, underpinned by the view that inquiry concerned students' curiosity:

> 'I think it([inquiry)is quite loose and I think it is about exploring and …. about giving a lot of scope to children to learn to investigate things and think about things that they have not thought about and they come up with questions that you as a teacher wouldn't have thought of asking and it is about being inquisitive …….and it is a really good way to engage children in science as it is absolutely what it is about in university and beyond. It is about taking the problem and coming up with the solution but more than that it is about working out how to use the apparatus, that we already have, to investigate - which I think is a neglected skill at the moment…. As a lot of skills and definitions you can learn but being inquisitive you have to find and develop rather than just be taught it.'

Research question 2: What inquiry learning science opportunities do pre-service teachers consider botanical gardens offer?

Pre-service biology teachers identified various inquiry learning-related opportunities available in botanical gardens. The majority of the inquiry opportunities listed were not specific to the context of a botanical gardens but rather could be transferred to multiple informal settings. That is, participants listed inquiry opportunities as: prompting questions, stimulating thought, triggering curiosity ('seeing strange things') and creating the possibility for self-directed and autonomous learning. Frequently, participants conflated inquiry learning with learning outside the classroom, such as a botanical garden. For example, in response to a question concerning inquiry learning four participants highlighted that the Garden offered 'memorable experiences' and 'authentic science'.

For the two participants who did identify opportunities specific to a botanical garden, developing scientific observation was key. This affordance was aligned with the opportunity for conceptual understanding in biology-related topics including variation, adaptation and evolution. Emily, for example, suggested that botanical gardens offered an opportunity to study organisms in their 'natural' environment: 'I think for science, seeing plants and animals in their climates it is really useful in relation to adaptions and evolution' and Bethan suggested the Gardens offered an opportunity 'to see that there is a whole Alpine house of multiple examples' to compare and consider.

Research question 3: What drawbacks do pre-service biology teachers anticipate to using botanical gardens for inquiry learning?

The pre-service biology teachers had few concerns about using botanical gardens for inquiry learning with several (3) participants stating that they could think of no drawbacks or concerns. This is counter to the prevailing belief that the majority of pre-service teachers are very concerned about teaching outside the classroom (Kisiel 2013). However, when participants did voice concerns they generally were related to managing inquiry learning. That is, first, a tension was identified between how open-ended an inquiry-based activity could be whilst maintaining student focus. For example, Emily, acknowledging the tension, highlighted the importance of an effective teacher-student relationship:

> 'It is such a large area. It could be difficult to control students. You need a good relationship with them and want to give them tasks that they can really focus on. So not just wandering around looking at things so that they might get a bit bored. There is a fine balance between searching out something, and really thinking about it, and just wandering about and getting bored.'

Similarly, Gina discussed the tension in terms of trust between teacher and students:

> 'So the drawback will be that it will be difficult to hand it over to them and hope they come up with questions and curiosities. I think it is a lot of trust…..If you've had the class for a while and you have trained them to think they probably will do quite well so it will depend on the class.'

The second concern related to managing inquiry learning was in terms of the practicalities. Hence, participants, referring to the Garden, were concerned about: the lack of physical boundaries (for example, classroom walls), the students' interaction with the general public and the potential health risks (for example, poisoning from plants and falling over).

Research question 4: How are pre-service biology teachers' views of inquiry learning and botanical garden learning related?

In answering this question, we explored the relationships between the pre-service teachers views of inquiry learning as they tried to articulate how this might be developed in a botanical garden. It was clear that many of the views that steered the pre-service teachers' ideas about the nature of science, inquiry and pedagogy were also prevalent when they considered teaching outdoors. This enabled us to develop an interpretative framework (Table 1) to understand better the range of views expressed. Hence, when we explored the participant's views of inquiry learning alongside their views of inquiry opportunities in botanical gardens, three broad categories of views emerged which ranged from naïve (View 1) through to developing sophistication (View 3). So pre-service biology teachers' with a view of inquiry as 'learning from doing' were found to view inquiry opportunities in botanical gardens as offering 'memorable experiences'. We categorized these views as simple and uncomplicated with limited affordances expressed for inquiry learning outside the

classroom (View 1). Whereas, pre-service biology teachers with a view of inquiry as complex, driven by curiosity, expressed through questioning and scientific observation were found to view inquiry outside the classroom as an opportunity to encourage students' autonomy by cultivating students' scientific interest in 'authentic settings'. These pre-service teachers realized that there were increased opportunities for inquiry learning offered by the botanical garden. We categorized these views as complex, as whilst these pre-service teachers understood the affordances for inquiry in outdoor settings they also acknowledged the settings' challenges.

Table 1: here

Participants categorized with naive views (View 1) of inquiry learning and learning in informal settings were generally identified as focused on the requirements of the curriculum and formal assessments. Caroline, was categorised as having View 1:

> 'If they are doing inquiry based learning it might not be always brought back to the syllabus that they are learning ….It might not be relevant to the exam question they are eventually going to answer…The examples are not as structured or specific to the syllabus they are learning but it might help them later on and in later years. There is a lot of avenues to go down in Kew, but if you are teaching in the classroom you are teaching to the curriculum, that's what you are sticking to for example, so they don't get confused. For the more able students they know what is relevant, to what they need to answer in the question, to what isn't. For lower ability learners, although it is good for them to do things that are practical, they might not be able to differentiate between what applies to the question, that is what they need to know, and what is extra information.'

Participants categorized with complex views concerning inquiry learning and learning in informal settings stressed the need 'to ensure maximum benefits' of the visit by tying the inquiry learning from the Garden back into the classroom and vice versa. That is, the visit needed to be integrated into the learning sequence so that pre-and post-activities were thoroughly planned. Although similar, this view was articulated differently from the explicit need to link learning to the curriculum or to formal assessments. Rather, pre-service teachers categorized with a complex view (View 3), foresaw the potential challenges to ensure that

whilst inquiry learning built on students' prior knowledge, this learning needed to be transferred into the real world setting and eventually brought back to, and made sense off, in the classroom. These insights presented challenges for two participants as they initially spoke about inquiry learning enabling student autonomy, but struggled to articulate a pedagogy that enabled this, without giving up the control they felt they required:

> 'What will be difficult will be doing a follow-up class that really gets the benefit of what they have found. I think it is really important to ask students what they have learnt and, in fact, do it before - tell them what they are looking for - as I think it would be quite easy to wander around and say that is a pretty plant and not think about it. So it is important to give students good questions to think for themselves to give them how to look and what to look for and follow it up afterwards……. I think in a pre-class, you could give them basic questions or, in school, we gave them question words and we gave them keywords and we asked them to put them together to make questions. As I do not think you can say to a child - come up with a question or a good question, especially if you want next level (higher order) questioning.' (Gina)

Implications

Our findings indicate that innovation is difficult to implement, even when introduced early in emergent pedagogy, as with these pre-service Biology teachers. For some pre-service teachers, the complexity of what the inquiry practice might construe proved too great a step for them to envisage. For others, while there was an appetite for introducing inquiry learning to help students explore and make meaning in an outdoor setting, several contradictions and conflicts arose (Engstrom 1999), which led to constraints in the implementation. This has led us to believe that a longer time frame and more staged introduction to inquiry learning is required, before we add the challenge of performing inquiry in an outdoor setting.

At a local level, the three level variation in response from the pre-service biology teachers has led us to consider the course sessions that we provide on the nature of science, inquiry and learning in informal settings and how we might more readily support beginning teachers in developing appropriate pedagogies. This may mean that we need to take a more differentiated approach to the earlier part of the pre-service course so that pre-service

teachers can, in their own time, come to terms with how they introduce and blend these types of pedagogy into practice. Expanding the vision of where science inquiry learning can happen early for beginning teachers may increase their interest and confidence in the use of the outdoor learning environments for science teaching (Fiennes et al. 2015) and pre-service courses may need to be more flexible in accommodating diverse needs as beginning teachers' pedagogy emerges.

For schools, we feel that a similar problem exists. Outdoor learning is a novel approach for many teachers and attempting to transform the 'normal classroom teaching' in approach, as well as context, may be too great a challenge to achieve in a single visit. We would therefore advocate a series of linked visits to an outdoor setting, so that teachers can gradually make sense of their context and gain the confidence to allow more student agency for learning in an outdoor setting. An alternative or addition to this might be a linked introduction and followup session for the outdoor visit within the normal classroom to allow a more mediated and gentler introduction to inquiry learning.

Conclusion

This paper has considered the views of pre-service secondary science teachers of inquiry learning during a visit to a botanical garden. Pre-service biology teachers differed in the ways they responded to an opportunity to develop inquiry learning in a botanic garden setting. Evidence suggests that pre-service science teachers are aware of the affordances of inquiry learning. However, they are concerned about ensuring a diversity of learning outcomes, the control of learning and the potential direction and openness of inquiry. This concern is compounded by the richness and diversity on offer in botanical gardens to inquiry. Taken together, these factors bring a unique set of challenges that have the potential to overwhelm pre-service teachers in the early stages of their professional development. Trying to make sense of a pedagogy that suggested greater student agency caused them varying degrees of concern as to the feasibility of such an approach, while their varying conceptualisations of the nature of science encouraged many of them to consider how it might develop students' curiosity and motivation.

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Table 1.
Pre-service biology teachers' view of inquiry learning and botanical garden learning

Description of inquiry learning and botanical garden learning views	**Teachers' view of inquiry learning**	**Teachers' view of inquiry opportunities in botanical gardens**
View 1: Simple/technical uncomplicated view of inquiry and informal settings	Learning from doing, making mistakes	Memorable experience
View 2: Inquiry learning and informal setting learning viewed as opportunity to initiate student agency over science learning	Teacher set up questions but also encourage students to set own questions Making observations to think.	Space used to answer questions, collect evidence, find the right answer and stimulate thought, provides material for thinking. It is where 'real science' occurs, similar to in universities
View 3: Views inquiry learning as complex. Considers inquiry in botanical gardens as useful context for skill & conceptual development.	As above, plus develop technical skills, engender both scientific and place-based curiosity	Space to open up curiosity, offering 'authentic' science similar to university science. It is self-directed which cultivates students' interest in the real world. Offers multiple examples of organisms living in situ for studies including adaptation, evolution, and variation.